ECONOMIC FEASIBILITY OF MASS PROPAGATION AND DISTRIBUTION OF THE *CATOLACCUS GRANDIS WASP* FOR USE IN BOLL WEEVILSUPPRESSION

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Abstract

Suppression of the boll weevils continues to be a concern in portions of the Cotton Belt as well as neighboring production areas in Mexico who do not have formal boll weevil eradication programs. Ongoing research has produced an alternative method of control which involves the release of the boll weevil's natural enemy, the *Catolaccus grandis* wasp. This paper examines the economic feasibility of constructing a facility for the mass propagation and release of the *Catolaccus grandis* wasp for suppression of the boll weevil. Results suggest that this biological approach to pest management could be accomplished for $22.65 per treated acre. Sensitivity analysis is performed to examine further areas of cost reduction as well as economic factors which might alter the estimated cost of using this biological control method. In addition, the EPIC-WQ model is employed to assess the environmental consequences of the conventional and biological methods of boll weevil suppression.

Introduction

Significant economic losses continue to accrue due to boll weevil infestations throughout the nation. As a regional example, the Texas High Plains has recently experienced greater numbers of over-wintering boll weevils, and such increased pest pressure is projected to continue in the future. A recent economic study for that region estimates the boll weevil will result in a reduction in farmer profits of $142 million per year, shift of 500,000 acres from cotton to an alternative crop, and a loss in business activity for the region of $500 million (Task Force Report, 1997). This problem is similarly acute in the Lower Rio Grande Valley of Texas where 1995 cotton production fell to 70,000 bales; 78 percent below the average of the previous three production levels (Texas Crop Reporting Service, 1992-1995).

One potential response to the boll weevil threat includes use of an area-wide eradication program similar to those used in the non-fringe areas such as the Carolinas, Georgia, California, and Arizona. Such a program was tried and subsequently rejected in the Lower Rio Grande Valley of Texas. Secondary pests, free to act due to heavy spraying and the resulting removal of their natural predators, caused major damage to the cotton crop. In such circumstances use of the boll weevil's natural enemy, the *Catolaccus grandis* (C. grandis) wasp, appears to be an obvious choice for treatment. Such a choice is predicated on the treatment being both technically and economically feasible.

Research efforts employing C. grandis for boll weevil suppression have a strong history (King, et al., 1993). Such research has been spearheaded by the ARS Subtropical Agricultural Research Lab and Biological Control of Pests Research Unit at Weslaco, Texas. Experiments conducted in the Lower Rio Grande Valley in 1992, 1993, and 1994, Alabama in 1993, and in the Texas Southern Rolling Plains in 1995 demonstrated that releases of C. grandis females at rates of 350 to 1,000 females per acre per week for six to eight weeks during early season (beginning with occurrence of 1/4-inch diameter squares) can cause up to 90% mortality of weevil larvae and pupae.

In 1995, 350 female parasites per acre were released in 204 acres of skip-row, organically-grown cotton. Based on samples taken from the field on a weekly basis, no weevil survival was detected for six consecutive weeks after releases were initiated (Coleman et al., 1996). Captures of adult weevils in pheromone traps surrounding the parasite-release and eradication-fields were significantly higher throughout the test (July 15-September 15) in the eradication control fields than in the parasite-release fields. Late-season migration of adult weevils from nearby cotton fields coupled with termination of parasite releases (September 15) resulted in low level, in-field reproduction by weevils.

The latest field trials have applied 250 female wasps per acre twice per week for six consecutive weeks. Three thousand wasps are therefore needed per acre treated in a season, and very large-scale production facilities are required to service even 100,000 acres. Nearly 31 million wasps per week are required assuming a 10% mortality rate and 90% female population. "Training" of the parent colony female wasps takes place by exposing them to boll weevil larvae and results in the apparently disproportionate number of female wasps produced. This is advantageous given that the female wasp lays eggs within the desired target boll weevil larvae in the field.

Commercial production and distribution of the Catolaccus grandis wasp represents a ground breaking biological approach in control of the boll weevil with several potential benefits including preservation of beneficial insects, reduced pesticide pollution, and increased profits to cotton growers. The USDA, ARS in Weslaco, Texas has been doing research on rearing of C. grandis as well as effects of releases in cotton. There is a vast set of literature from the work at Weslaco and other regions in Texas indicating that C. grandis is an effective biological control measure for the boll weevil.

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For effective control of the boll weevil, however, multiple releases of C. grandis over about six weeks in cotton is required.

In addition to the technical feasibility issues related to the C. grandis wasp, a further and perhaps more binding issue relates to the economic feasibility of C. grandis as compared to conventional boll weevil control methods. Current conventional means of treatment consist of 4 to 10 insecticide applications with total treatment costs ranging from $40 to $110 per acre. Robinson et al., (1995) provided initial estimates of rearing of C. grandis in 1994 based on the level of technology at that time. Estimated costs per acre for C. grandis at that time were in the $50 to $80 range. The purpose of the economic analysis reported herein was to: (1) gather base information related to costs of rearing and distributing C. grandis; (2) conduct an economic feasibility analysis of constructing a large-scale facility for the mass propagation and distribution of the C. grandis wasp; (3) identify further areas of potential cost reduction through sensitivity analysis and scenarios and (4) examine the environmental consequences of the conventional and biological control methods.

Procedures

This economic feasibility study was designed to estimate the costs per acre of rearing and distributing C. grandis for boll weevil control. This requires gathering the best information possible on investments, maintenance and repairs, and variable costs to operate a facility. A workshop was organized and conducted on March 5 and 6, 1997 at the ARS facilities in Weslaco. The purpose of the workshop was to develop estimates of the size of plant to consider, review technologies for rearing C. grandis and assign costs (investment and out of pocket) to each component of the system. There were over 30 participants representing ARS, Texas A&M University Agriculture Program, APHIS, Texas Department of Agriculture, Cameron County farmers, private sector related to rearing, interests in Mexico including INIFAP, Sanadad Vegetal, and AMSCO-OP, and economists from Mississippi and Oklahoma that had done previous analyses of C. grandis.

The workshop participants established the desired facility capacity at a production level of 62 million C. grandis wasps per week in order to accommodate treatment of 300,000 cotton acres. From this capacity basis, the discussion moved into other assumptions to establish a base case scenario. Then, more specific inquiry related to: the investment required, interest rate to use, required equipment along with expected life and cost, time to set-up the facility and to operate and shut-down the facility, items and costs associated with production, and the distribution of wasps from the facility to fields in South Texas, other regions of the U.S., and to Mexico could be considered.

A base case for the economic feasibility estimate was established. From this base case, alternative scenarios and assumptions could be evaluated through sensitivity analysis. Because the base case is the estimate of the most likely case at this time, the assumptions are critical. They consist of the following: (1) the facility would provide 50 million living female wasps per week to the field; (2) three regions would be provided with wasps with each treating 100,000 acres, these regions and dates for wasp distribution were identified as: Area I - Rio Grande Valley of Texas (April 15 - June - 15); Area II - Fringe area of Texas High and Rolling Plains (June 16 - July 31); and Area III - Southern Mexico (August 1 - September 15); (3) female wasps account for 90% of production, and 90% of the wasps produced are available for distribution (i.e., facility produces a total of 62 million wasps per week, with 90% female and 10% mortality from rearing facility to the field); and (4) the facility will operate continually after start-up and production would be required for 20 weeks to allow for overlap in the production of 18 weeks of distributed wasps.

To develop an estimate of the costs of C. grandis as a biological method of boll weevil control, investments and operational costs must be put on an annual basis. For operation and maintenance this presents no problem. However, for investments that last over several years, there are alternatives. To annualize investments, the investment was amortized over the years of life of the item (building, equipment, vehicles, etc.) at an interest rate of 9%. Such a method for annualization of investment can be interpreted as assuming that all of the investment is borrowed and then repaid over the life of the item. At the end of the life of the item, this particular item must be purchased and the process continues.

For many of the activities, the analysis relies on custom costs. To transport C. grandis to other regions of Texas or Mexico, commercial airlines were used to estimate costs. Distribution of wasps in cotton fields was based upon an hourly fee for custom application by plane. Annual costs were developed for taxes, water, insurance, utilities, repair and maintenance, disposal of wastes, and vehicle upkeep. Estimates were developed for supervision costs, labor, supplies, diet and similar needs. A simple multiplication of the amount by the cost per unit gives variable costs of production (see tables 1 - 3 for these items and calculations).

The development of the base case is presented initially, followed by the results of the analysis and implications under sensitivity analysis and two alternative scenarios. An environmental assessment is then reported, examining potential reductions in pesticide loadings accompanying use of C. grandis. Using the EPIC-WQ model, reductions are reported for both leaching into groundwater as well as surface water runoff. Finally, conclusions and implications for further research are highlighted.

Base Case Scenario

As indicated above, a rearing facility capable of producing 62 million wasps per week was examined. Ninety percent of the C. grandis wasps reared are assumed to be female, yielding 55.8 million females available for distribution. Ten percent mortality is assumed for transport and delivery to the field, resulting in a net 50.2 million live female wasps delivered to fields weekly. Five key areas are discussed with the initial component being the costs of investment. Reporting of the non-material annual costs of production follows, and is accompanied by a listing of the cost of materials needed for production of the wasps. Fourthly, costs for transport to regions outside the Lower Rio Grande Valley as well as distribution across cotton fields is then covered.

Table 1 shows investment factor costs. For the rearing facility, an improved land area of two acres was established. On this land a building with 14,700 square feet was developed where there would be 9,900 sq. ft. of rearing space and 4,800 sq. ft. of common area for offices, meeting rooms, restrooms and other general needs. Expected investment for land and buildings totals $2.13 million with an additional investment of $1.18 million for equipment in the building, $258,000 for installation, and $95,000 for vehicles. The annual amortized equivalent of this investment is $539,668 based on a 9% interest rate and the respective years of life assumed for each item.

Another set of annual costs were estimated and which are to an extent variable. However, for this analysis, many of these are costs which must be incurred regardless of the level of C. grandis production (such as taxes, insurance, repair and maintenance). Other costs calculated were management labor, shift labor, repair and maintenance, utilities, operation of vehicles, and a research and development fund. Table 2 presents a listing of these costs on an annual basis.

Management costs are estimated as $430,000 per year including several permanent employees. Once the plant begins to come into production, it is assumed that there is a period of three weeks where a total of 1,680 hours are needed to begin building the stock of wasps. This is followed by another three week period of accelerated production of wasps and a doubling of hourly employees where total hours would be 3,024. Once the plant is in full production, it operates at full capacity for 20 weeks using 18 workers and involving 40,320 hours. At the end of the season, a shut down phase is only 560 hours. Total hourly labor was estimated to be $319,000 for one year.

Additional costs in table 2 include taxes, insurance, vehicle operation (assuming three vehicles traveling 30,000 miles per year each and a cost of $0.28 per mile), water, utilities, and property taxes. Repair and maintenance plus property taxes represent about a quarter of a million dollars, with annual direct operating costs totaling around $735,000. A research and development fund was also included to fund improvement in rearing techniques as well as maintaining a competitive position in the market. This fund was assumed to be 10% of the $735,000 direct operating costs, or $73,500 per year. Total annual operating costs are an estimated $1.56 million.

Rearing of the C. grandis requires a continuing flow of diet, parafilm, and other materials. Table 3 shows the materials as well as costs expected for production for one year. The materials required to produce C. grandis are based on experience with the wasp as well as activities in rearing of insects at other facilities. Artificial diet costs for the base case are $2.35 per 1,000 wasps, which is the cost for relatively low wasp production rates. It is clearly expected that weekly production in the 62 million range would bring about economies of size as well as quantity discounts for diet components. Potential cost savings accompanying such discounts are addressed in the sensitivity analysis. Total costs of material for rearing is an estimated $4.78 million per year.

The last major cost item estimated for the C. grandis operation was transportation to regions and distribution across cotton fields. For South Texas, it was assumed that the wasps would be loaded on the vehicles and transported to planes for application. For other regions, commercial airlines and associated rates were used. Then at the remote region, a holding facility and transportation to the surrounding area for pick up by application planes was considered. Wasps are assumed to be applied at a rate of 250 live females twice a week for six weeks. Application takes place in the cool of the early morning or evening to limit heat related mortality.

The size and distribution of fields has a dramatic impact on costs of field application. For South Texas, field sizes in the 30 to 40 acre range were assumed with three such fields aligned for aerial application. This implies that the plane spends large amount of time turning. In contrast, the larger fields of the Texas High Plains and Southern Mexico carry significantly lower field distribution costs. With a region-wide program, there is an opportunity to coordinate fields in South Texas so that several farms were treated in a single straight line pass. The pilot would simply not apply wasps over fields of crops that were not in cotton. This would reduce the costs of application for South Texas.

Based on typical field sizes, custom rates for aerial application, and commercial shipping charges for transporting cargo, the annual cost for transportation and distribution of wasps to the three regions was estimated to be $667,000. South Texas accounts for nearly $400,000 of this cost while the Texas High Plains and Southern Mexico are over $100,000. This is due to larger fields reducing costs of field application. An annualized retro-fit cost of $43,810 was estimated to make eight planes applicable for distribution of C. grandis in cotton fields. Four of the eight would be ferried to the outlying cotton production regions for use later in the season. A complete detail of these cost estimates can be found in Ellis et al., (1997).

A critical need in an economic feasibility study is to consider alternatives and costs under them. From the workshop, the group worked in a modified Delphi process to develop estimates for what could be reasonably expected in an expanded application of C. grandis management driven boll weevil control strategy. In addition, data and estimates were developed from input from other researchers and the private sector. Nevertheless, there are many factors for which the value cannot be defined with great accuracy. To provide some insight into the impacts on costs of using C. grandis for control of boll weevil over a range in values for selected factors, sensitivity analysis was done.

The base case scenario for these various cost items are identified, and the sensitivity analysis included: (1) three artificial diet costs per 1,000 wasps of $1.18, $2.35 (base case) and $3.50; (2) two facility construction costs ranging from $1.1 million to $2.1 million (base case); (3) facility construction costs amortized over two different periods, 10 years (base case) and 15 years; (4) two interest rates for amortization and cost of capital, 9% (base case) and 12%; and (5) serviceable areas of 300,000 acres (Areas I - III) (base case), 200,000 acres (Areas I and II), and 100,000 acres (Area I only).

Results

By accumulating the costs from tables 1 - 4, a total annual cost associated with rearing, transportation and distribution of C. grandis from a plant producing 62 million wasps per week comes to $6,794,846. This is for the base case scenario and assumes three regions of cotton will be treated and 100,000 acres will be treated in each region. Therefore, $6.8 million spread across 300,000 acres implies the cost per acre would be $22.65.

Tables 4, 5, and 6 provide the basic results including the sensitivity analysis of important economic variables and are differentiated by the assumed number of production regions treated with C. grandis. Table 4 presents costs per acre for using C. grandis when all three production regions are treated (100,000 acres per region or 300,000 acres total) while tables 5 and 6 present the results for the two and single region scenarios. The majority of conclusions concerning the sensitivity of results to assumed parameter levels may be drawn from table 4 since the three region production scenario is the most likely of those considered.

For the base case scenario (table 4), it was estimated that the cost of rearing and distributing C. grandis as a means to control the boll weevil was $22.65 per treated acre. The estimated costs for the 300,000 acre serviceable area scenario ranged from $15.62 to $29.20 per acre depending upon the combination of economic variables considered. The impact on this estimated cost, or sensitivity to the economic variables are discussed later. However, from table 4, the sensitivity analysis helps to identify those items (diet cost, interest rate, facility construction cost, etc.) which have the greatest potential for reducing costs of using C. grandis for biological control of boll weevil. These estimated costs fall well below the current costs of conventional pest management strategies for both dryland and irrigated cotton operations in the Lower Rio Grande Valley.

The results for the scenario and sensitivity analysis for a serviceable area of 200,000 acres are reported in table 5. For this scenario, it was estimated that the cost of rearing and distributing C. grandis as a means to control the boll weevil ranged from $19.15 to $34.89 per acre depending upon the combination of economic variables considered. Therefore, the impact of a 100,000 acre reduction in the serviceable area for C. grandis distribution from this facility is estimated to raise the cost of biological boll weevil control between $3.53 per acre and $5.69 per acre over the base case scenario (300,000 acres) depending upon the combination of economic variables. Again, these estimated costs are below the current costs for conventional pest management strategies for both dryland and irrigated cotton operations in the Lower Rio Grande Valley.

The results for the scenario and sensitivity analysis for a serviceable area of 100,000 acres are reported in table 6. For this scenario, it was estimated that the cost of rearing and distributing C. grandis as a means to control the boll weevil ranged from $29.58 to $51.50 per acre depending upon the combination of economic variables considered. Therefore, the impact of a 200,000 acre reduction in the serviceable area for C. grandis distribution from this facility is estimated to raise the cost of biological boll weevil control between $13.96 per acre and $22.30 per acre over the base case scenario (300,000 acres) depending upon the combination of economic variables. Further, the costs of biological control with C. grandis begin to approach, and even exceed the costs of conventional pest management strategies on dryland cotton operations, but are still below those for irrigated cotton operations.

Sensitivity Analysis

Initial Facility Cost: There is some uncertainty as to the initial cost of the facility. A lower estimate values the 4,800 square feet of common space at $50 per square foot and the 9,900 square feet rearing area at $80 per square foot. Two acres of improved land is valued at $35,000, yielding an initial cost of $1.1 million for the facility. These values are believed to be possibly low and were therefore doubled to a conservative base case for an initial facility cost of $2.1 million. For the base case scenario values of 9%, 10 years, and a diet cost of $2.35, the projected per acre wasp treatment cost is $22.65. The less expensive facility under the same assumptions decreases that cost slightly to $21.82. Initial facility outlay appears to matter little in final per acre costs for use of C. grandis, especially when all three production regions are considered. These values change slightly, however, when the plant is only used to service two cotton production areas (table 5). Fixed costs of investments are spread across fewer acres, resulting in projected per acre production and application costs of $26.18 and $27.47 for the $1.1 million and $2.1 million facilities, respectively. These costs increase dramatically to $39.08 and $41.56 per acre if only one region (the Rio Grande Valley) is available for distribution (table 6).

Artificial Diet Cost: Currently, the cost of artificial diet is $2.35 per 1,000 wasps. This cost is for a very low level of wasp production compared to the planned 62 million per week target production level and comprises approximately 55% of the variable annual operating costs if all three production regions are served (total of costs in tables 2 and 3). A cursory check on advantages of large scale production revealed that the diet components could be procured at about 50% of the current cost. The effect of the cost for artificial diet is presented in tables 4-6. Once again, moving from the base case presented in table 4, cutting the diet cost from $2.35 to $1.18 per 1,000 wasps reduces the per acre cost for use of C. grandis from $22.65 to $16.59 per acre. The converse is an increase in diet cost and the cost per acre goes to $28.61 if cost rises to $3.50 per 1,000 wasps. This is about a $6 change in cost per acre for C. grandis by cutting diet cost and is over a 25% reduction in per acre cost. Diet cost is definitely a factor of cost with great potential for improving the economic position of C. grandis.

Treated Acres: The base case for the economic feasibility study was that there would be three regions of treatment with 100,000 acres of cotton in each region treated. However, the issue of less acres treated will have an important effect on the cost of C. grandis on a per acre basis since the number of acres that fixed costs are spread across is changed. For this case, table 4 represents the three regions with a total of 300,000 acres treated, table 5 is two regions and a total of 200,000 acres treated, and table 6 is one region and only 100,000 acres treated. If the treatment area declines to two regions and 200,000 acres, then the cost per acre increases from the base case value of $22.65 to $27.47 per acre (an increase of 21%). By constraining the service area to just 100,000 acres, the cost per acre rises to $41.56.

The observations above reinforce the age old truism that marketing is critical. By increasing acreage there is an opportunity to further reduce cost per acre. An objective of the plant, once constructed, will be to maintain production for as long as possible at near capacity. This can be accomplished by expanding wasp delivery to other regions of cotton production as well as looking to production of other insect predators for use on other crops and for other times of the year.

Interest Rate : Results in table 4 portray littleimpact of the assumed interest rate on the overall cost. Increasing the assumed rate from 9% to 12% for the base case scenario increases the cost per acre by $0.50 to $23.15 (table 4). Similar comparisons in tables 5 and 6 show minor increases (<3%) in the cost of production and application for all scenarios switching from 9% to 12% amortization factors. Overall, for interest rates of 9% and 12%, the difference is not dramatic and the change in per acre costs minimal.

Years of Facility Life: The longer an investment in a plant can be used, typically the lower the annual cost associated with the investment. Therefore, an assumed 10 year life for the plant was compared to a 15 year life. This is shown in tables 4-6 and as above had very little affect of costs per acre. The 15 year life is associated with just over a 1% reduction in costs per acre associated with C. grandis. Years of life of the plant between 10 and 15 is not significant in reducing costs per acre.

In addition, two more scenarios were also examined and contrasted with the base case without examining all of the various combinations of interest rate, diet cost, etc. These later two alternatives include an examination of the impact of not having to treat each acre of cotton explicitly (i.e. greater efficacy of C. grandis), and a second option of eliminating the current practice of exposing C. grandis wasps to boll weevils as “training” and to accelerate egg laying.

Greater Efficacy of C. Grandis

There is much to be learned in the distribution of wasps to cotton fields. The levels used for this analysis is based on experiences to date and are in the range of a fail-safe density. However, with experience it is expected that the density and concentration of wasps can be reduced for the same level of boll weevil control. To provide some insight into the impact, this study assumed that the same level of boll weevil control could be achieved on four acres for each three acres treated in the base case. The base case assumed delivery of 250 wasps twice per week for six weeks to each acre. Treating three acres to get four acres of boll weevil control reduced the needed wasps from 50 million per week to 37.5 million per week for 100,000 acres of control. Analogous production levels at the rearing facility are reduced from 62 million to 46.5 million wasps per week.

These reductions were assumed to take place at the plant rather than expanding the potential acreage served. Rearing facility capacity was kept at the base level but variable factors such as diet and labor were reduced to accommodate the lower required production. Using this approach, the cost per acre declined from $22.65 to $18.30. These results demonstrate that use of a reduced number of wasps applied per field holds great promise as a further means of increasing the competitive advantage of C. grandis treatment of boll weevil. Further field testing and large scale demonstrations are needed to determine the optimal economic levels of wasp application.

Elimination of Boll Weevil Larvae in Rearing

Currently it is necessary to expose the C. grandis to boll weevil larvae to induce egg lay. Research scientists are confident that this step may be eliminated, reducing the need for $250,000 of equipment as well as 750 square foot of rearing space. In addition, three workers per shift would not be required and the amount of artificial diet required would be reduced by 10%. Considering these effects, the cost per acre of treatment of C. grandis would be reduced from the $22.65 of the base case to $21.12.

Additional potential benefits of eliminating the boll weevil larvae exposure step in the production process would be that pupae stage wasps could be released in the field instead of adult wasps. Established aerial distribution techniques for pupae stage insects are already well established and could reasonably be adapted for the C. grandis, thereby eliminating or reducing the need for new custom techniques and equipment for aerial distribution of adult wasps.

Environmental Analysis

A last part of the analysis was application of the EPIC-WQ (Erosion Productivity Impact Calculator - Water Quality) model to simulate fate and transport of pesticides in a representative cotton field in South Texas for a conventional system as compared to use of C. grandis. The model is a biophysical simulation model developed by the USDA-ARS in the early 1980's. EPIC-WQ runs on a daily time step and simulates the interaction of soil erosion, plant growth, weather, hydrology, nutrient cycling, tillage, soil temperature, and economics. Up to 10 soil layers can be used.

EPIC-WQ has been tested extensively and used in many local, regional, and national studies of the effects of weather, soils and agricultural management practices on crop yields, soil erosion, nutrient cycling and pesticide movement. The model is described in detail by Williams, Renard, and Dyke (1983) and by Sharpley and Williams (1990).

Two boll weevil management strategies were evaluated using the EPIC-WQ model. A conventional boll weevil strategy was evaluated that used seven boll weevil specific insecticide applications. This was compared to C. grandis being used in conjunction with one boll weevil application. The pest management strategies were:

Conventional Management:
Mid April: One application for fleahopper (.25 lb. of active ingredient).
Late April to early June: 7 applications for boll weevil (.25 lb. of active ingredient).
Late June - Early July: 1 to 2 applications for bollworm (.3 lb. of active ingredient).

Biological Management:
Mid April: 1 application for fleahopper (.25 lb. of active ingredient).
Late April: 1 application for boll weevil (.25 lb. of active ingredient).

A Harlingen Clay soil was used for the EPIC-WQ application. The model generated weather data for the region (Lower Rio Grande Valley). Three 6 inch irrigations were applied using furrow irrigation, and irrigation distribution efficiency was assumed to be 70%. Typical fertilization, tillage and other management practices were taken from the Texas Agricultural Extension Service Crop Enterprise Budgets for the region.

Table 7 shows the preliminary implications of pesticide in runoff and leached for the two pest management systems as well as the expected yield. Percent declines from the conventional treatment are shown in parenthesis. This is a preliminary analysis using EPIC-WQ and the absolute values are not as important as the relative values. For the comparison, pesticide simulated in runoff are only one-third as much where C. grandis was used as compared to conventional boll weevil management practices. For pesticide leached, the concentration associated with C. grandis was less than 50% of that projected for conventional practices. Lint yield was estimated to be four pounds greater for the conventional boll weevil management practice.

The results generated by EPIC-WQ are sensitive to the timing for irrigations, pesticide applications and tillage practices. In applying biophysical simulation models, it is critical that the coefficients and processes be validated using research, demonstration of field data. Because EPIC-WQ has been applied on more than 170 sites in the U.S. as well as around the world with success, there is a comfort level in its use. However, additional work is needed on validating the model for the Lower Rio Grande Valley of Texas. At this point, we are comfortable with the
relative measures comparing conventional boll weevil management strategies to C. grandis.

Limitations and Conclusions

A multitude of factors were considered in this economic feasibility analysis. For the base case, the assumptions and conditions are conservative. For example, the artificial diet was charged at $2.35 per 1,000 wasps. There is strong evidence that this can be reduced by 50% for a large scale rearing plant. Weslaco researchers are also confident that additional progress will be made in eliminating the boll weevil larvae exposure step as well as reducing the number of wasps used to treat each acre of cotton. Initial rearing facility construction costs of $2.1 million are also conservative. The greatest areas of technological concern entails the methods for mass shipping of large numbers of adult wasps to distant locations as well as the aerial distribution once they are delivered. Cost estimates made here assume technologies for that facet of the operation are feasible and the values assumed for the cost of that step are the best available at this time. Additional unknown factors could increase the projected costs developed here, but the $22.65 per acre for production and distribution is a reasonable estimate based on current knowledge of the use of C. grandis in control of the boll weevil and may be used confidently for planning. Additional reductions in cost could be achieved by serving more cotton production areas or acres as well as producing other parasitic insects during the off-time of C. grandis production.

The estimated cost of $22.65 for biological control of the boll weevil brings to light several conclusions. First, is the great strides in research and development that have occurred over the past three years as this figure is some $28 to $58 below the estimated cost just three years ago. Secondly, is the apparent economic feasibility of biological control when compared to the current $40 to $110 cost of conventional pest management strategy. Finally, there is the evidence from the EPIC-WQ model that indicates an environmental preference for biological control over conventional pest management. This aspect might prove especially valuable in environmentally sensitive production areas such as the Lower Rio Grande Valley. Taken together, these conclusions point to the need for further research to continue refining the research program related to C. grandis as a viable alternative for suppression of the boll weevil.

There are also many assumptions underlying this study. Each assumption may also represent a limitation. In addition to the assumptions listed at the beginning, there are additional issues which deserve to be considered. First, an exact six week period of treatment for each region was assumed. However, it could be longer or shorter and there might be overlap in application between regions. Secondly, including a region in Mexico may include some costs of international business that are not included in this analysis. Next, an insurance cost is not included for the boxes of wasps being transported to different regions where each box contains 4.8 million wasps and might be worth as much as $80,000. The operation is assumed to be self-insured. Additionally, the transportation of wasps in large numbers to other regions is based on developing technologies for packaging that is amenable to commercial air and where a large number of wasps can be put in a relatively small container. This is not existing technology and a high priority for further work before attempting to ship C. grandis several hundred miles. Finally, distribution of wasps across fields is assumed to be by plane. Machinery is needed to eject the wasps in a consistent flow to assure accurate application rates across fields. Again, there is a need for work before beginning large scale demonstrations.

There remains to be answered many unknowns related to large scale plant production of C. grandis and transporting to other regions of Texas (or the U.S.) as well as to Mexico. However, there is prior experience and evidence to support the values used and assumptions incorporated in this economic feasibility analysis. While the best current estimate of costs to produce and distribute C. grandis is $22.65 per acre, there are major opportunities to reduce this cost and approach the $15 per acre range. In addition to the proven record of technical feasibility for this biological control technology, it appears as if the use of the C. grandis is evolving toward being economically feasible as well and competitive with, and more environmentally friendly, than current conventional methods of controlling with the boll weevil.

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Table 1. Identification of investment items and amortized annual costs for a C. grandis rearing facility of 62 million wasps per week.

Item	**Investment Cost ($)**	**Useful Life (Years)**	**Amortized Value ($)**
Land	70,000	10	
Building			
Rearing	480,000	10	
Common	1,584,000	10	
Total	2,134,000	10	332,520
Bulding			
Equipment	1,175,000	15	145,769
Installation	258,000	10	40,202
Vehicles	95,000	6	21,177
Total	1,528,000		207,148
Total for All	**3,662,000**		**539,668**

Table 2. Estimated annual costs for operating costs associated with a C. grandis facility that produces 62 million wasps per week.

Item	**Amount**	**Cost per Unit**	**Total Cost ($)**
Management			
Shift mgrs.	4		
Field mgrs.	2		
Shop mgr.	1		
Total	7		430,000
Labor			
Start up I	1,680 hrs.	7	11,760
Start up II	3,024 hrs.	7	21,168
Normal	40,320 hrs.	7	282,240
Shut down	560 hrs.	7	3,920
Total	45,584 hrs.		319,088
Repar & Main.	3.3 million	4%	132,360
Insurance	25 million	115/million/mo	34,500
Water purif.		.	495
Vehicles	90,000 miles		25,200
Utilities	14,700 sq. ft.	0.28	8,085
Water	1,440,000 gal.	0.55	2,880
Property Tax	3.04 million	$.002/gal	101,370
Total		30/$1000 value	734,890
	734,890		
R & D		10%	73,489
Total for All			**1,557,467**

Table 3. Estimated annual costs for materials associated with a C. grandis facility that produces 62 million wasps per week.

Item	**Weekly Cost ($)**	**Weeks**	**Total Costs ($)**
Parafilm	6,354	24	152,496
PVC	10,333	24	247,992
Lidding	9,765	24	234,360
Artificial Diet	145,700	24	3,496,800
Disposal Cost	169	24	4,056
License Fees		52	125,000
Total			4,780,075

Table 4. Estimated per acre costs of C. grandis for alternative scenarios and assuming treatment of three areas totaling 300,000 acres.

		$1.1 Million Facility		$2.1 Million Facility	
Investment Period		10 Year	15 Year	10 Year	15 Year
Diet Cost $/1,000 wasps	Int. Rate	Treatment Cost Per Acre in Dollars			
$1.18	9%	15.76	15.62	16.59	16.34
	12%	16.10	15.97	17.00	16.76
$2.35	9%	21.82	21.68	**22.65**	22.40
	12%	22.25	22.12	23.15	22.91
$3.50	9%	27.78	27.64	28.61	28.36
	12%	28.29	28.16	29.20	28.96

Table 5. Estimated per acre costs of C. grandis for alternative scenarios and assuming treatment of two areas totaling 200,000 acres.

		$1.1 Million Facility		$2.1 Million Facility	
Investment Period		10 Year	15 Year	10 Year	15 Year
Diet Cost $/1,000 wasps	Int. Rate	Treatment Cost Per Acre in Dollars			
$1.18	9%	19.36	19.15	20.60	22.22
	12%	19.81	19.62	21.17	20.81
$2.35	9%	26.18	25.97	27.47	27.05
	12%	26.73	26.54	28.09	27.74
$3.50	9%	32.88	32.68	34.13	33.75
	12%	33.54	33.34	34.89	34.54

Table 6. Estimated per acre costs of C. grandis for alternative scenarios and assuming treatment of one area totaling 100,000 acres.

		$1.1 Million Facility		$2.1 Million Facility	
Investment Period		10 Year	15 Year	10 Year	15 Year
Diet Cost $/1,000 wasps	Int. Rate	Treatment Cost Per Acre in Dollars			
$1.18	9%	29.98	29.58	32.47	31.72
	12%	30.79	30.41	33.50	32.80
$2.35	9%	39.08	38.67	41.56	40.82
	12%	40.02	39.64	42.73	42.02
$3.50	9%	48.02	47.62	50.50	49.76
	12%	49.09	48.71	51.80	51.09

Table 7. Estimated pesticide runoff, percolation, and cotton yield as similated by the EPIC-WQ model in South Texas for conventional boll weevil management and use of C. grandis.

Item	**Conventional Pest Mgt.**	**Biological Pest Mgt. (C. grandis)**	**% Reduction by utilizing C. grandis**
Pesticide runoff	195 ppb	62 ppb	68%
Pesticide leached	76 ppb	34 ppb	55%
Cotton lint yield	722 lbs/ac	718 lbs./ac.	1%